15.0 CONCLUSIONS AND RECOMMENDATIONS

This project produced many useful results, while laying a foundation for both further research and improved operational freeway surveillance data processing software. Conclusions concerning these results are briefly presented, followed by recommendations for further research and measures to foster implementation.

15.1 Conclusions

Project results and their implications for application are discussed, first in terms of the algorithms and software delivered, and then in terms of their use in operational systems.

15.1.1 Algorithms and Software

The framework and individual surveillance data processing algorithms that have been developed in this project have immediate use in ATMS and ATIS systems. The preprocessing steps of malfunction detection, data repair and calibration are necessary precursors to the effective use of surveillance data in many applications -- certainly incident detection, as we have described here, but also in traveler information and ramp metering. Much of the processing software developed is in current use as a part of traveler information systems in Minneapolis and San Diego.

Existing incident detection algorithms used where congestion is prevalent are not operationally useful due to the very large false alarm rates. The preprocessing steps developed in this project, and the associated algorithms that discriminate incidents where congestion is found, provide an operationally useful capability.

In operational use, these algorithms locate and track congestion events. As each new such event is identified, the incident discrimination algorithm presents the estimated probability that the new event is in fact caused by an incident. In a typical case, the value of this probability might range from 5% to 80%, so that important information is provided that draws the attention of systems operators where there is strong evidence of an incident, e.g., when the probability is estimated to be 40% or so, but suggests that the congestion is most likely recurrent when this probability is low. The result is that fewer events need to be considered, and in those cases, priorities based on the probability can be assigned until an incident is confirmed, or the event is determined not to be an incident.

This project produced a substantial body of software, which we termed the Real-Time Incident Detection Environment (RIDE). RIDE incorporates all of the algorithms that were produced, and provides interfaces to both real data (from Oakland, Minneapolis and San Diego) and simulated data (from FRESIM). This software is fully documented in one of the volumes on the final report, and delivered as source code on a CD-ROM.

15.1.2 Applications for Operational Implementation

The algorithms documented in this report provide useful material for specifications for new operational freeway surveillance data processing software. The associated software, documented and delivered as RIDE, provide a body of useful prototype software.

The malfunction detection algorithms that have been developed can be used in a fairly direct manner in operational systems, as they are mostly phrased in terms of individual loops and mainline stations. Algorithms for data repair and calibration of single loops to produce reasonably accurate measures of speed in an operational form need much more work, mostly to reflect the operational features of specific systems. For example, in calibration, the key is to make regular independent measurements of speed with enough spatial granularity to distinguish actual variations in speeds as they occur over a freeway system. One way to do this is to install double loops or radar sensors at intervals to produce standard speed measurements, and associate each single-loop station with a standard speed measurement. At the extreme, single loops get replaced everywhere by double loops or another speed measurement technique.

In an operational environment, re-implementation of the remaining surveillance data processing algorithms, including queue identification and tracking and discrimination of congestion events, would be required and will entail a substantial software effort to model the roadway and its relationship to surveillance data. The project software documentation provides one model for how to do this: it uses a roadway-object orientation in the C++ language to organize all data and processing.

As these project results are absorbed by practitioners and systems builders, the project prototype software can also be used directly, since it has been developed to work in a stand-alone fashion using modular interfaces to real-time surveillance data. This use can be

valuable in familiarizing system operators with the new capabilities, and in fashioning the specific requirements for an integrated implementation.

15.2 Recommendations

Recommendations are offered here for further research, and for measures designed to foster operational use.

15.2.1 Further Research

FRESIM deserves additional attention to complete work necessary in making it suitable as the basis for further research on incident detection algorithms. Very considerable progress was made, generating simulations for about 50 directional miles for both the Minneapolis and San Diego area freeway systems for fifteen hours that were reasonably representative of daily, congested traffic. Improved flexibility in modeling, and improved modeling of congestion (both recurrent and non-recurrent) is needed.

The best opportunity for improvements in incident detection performance will come with better modeling generally, and in particular capturing recurrent congestion.   There are at least two approaches that could be considered:

Qualitative modeling using statistical approaches: With this approach, traffic zones are labeled over an extended period of time, to form a data base for statistical analysis that would lead to a characterization of recurrent congestion.   This approach would require a large effort to gather and label data, and any such effort would need to be repeated fairly often as the traffic conditions evolve from year to year.

Model-based approaches: With this approach, a macroscopic model would be created for the freeway system which would capture gross characteristics of each freeway segment, e.g., number of lanes, and local capacity.   Then recurrent congestion would in principle be predicted by application of the model using that day's surveillance data. The algorithmic basis of this approach is described in project documents, but we were not able to complete our work by applying this method to real data.

In either case, incidents would stand out as unexpected breakdowns or onset of congestion.

The simplicity of both the Bayesian approach and the California algorithms and their dependence on intuitively meaningful features suggest that these algorithms should transfer well, from the environment in the Twin Cities that was used for development, to other venues. The fact that training was done on such a large data set spanning a large freeway system with a great deal of variation in geometrics and traffic levels suggests that both the Bayesian and neural-net techniques should transfer well. It will be important to test the ability of these algorithms to perform usefully elsewhere.

In our examination of the I-880 data, where individual lane data was available, it was observed that the effects of an incident were frequently more pronounced in the lane data, and these effects were, on occasion, observable prior to any conclusive indications of an incident observed in the station average data. Research focused on exploitation of lane-specific data appears to be warranted.

The framework we have developed is believed to be useful where surveillance systems use alternative forms of surveillance devices, including radar and video cameras. New algorithms for malfunction detection need to be developed that are specific to the type of sensor. Each of the steps in the framework for surveillance data processing is largely independent of the specific type of point sensor, but further research is certainly warranted to test and improve the algorithms that have been developed.

15.2.2 Measures to Foster Implementation

The framework developed in this project represents a considerable departure from the currently held view of how incident detection can be accomplished in an operational freeway surveillance system. It will be important to convey to operational personnel and system developers that a new, systems approach, corresponding to the framework developed in this project, is essential to producing performance that will be useful in practice. The benefits of the new approach extend to a systematic means for the preliminary stages of surveillance data processing that identify malfunctioning sensors, for example, and serve as a basis for other applications, such as ramp metering.

The prototype software delivered, RIDE, coupled with the data visualization capabilities that reside in Ball's MetroView, offer a ready means to get this message across. This

combination can be implemented in a laboratory environment, in FHWA-sponsored Demonstration Projects, or can be adapted to additional operational sites, to demonstrate the new system elements and their benefits.